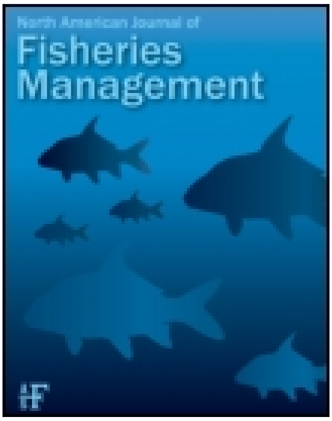

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Estimating Consumption of Freshwater Fish among Maine Anglers

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Abstract.—In deriving water quality standards and appropriate restoration levels for contaminated surface waters, the potential for human exposure is often the most important factor to be considered. For certain persistent compounds, like 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) or mixtures of polychlorinated biphenyls, a primary pathway of human exposure is through ingestion of fish obtained from affected waters. Pending water quality regulation for TCDD in Maine required that estimates be made of the rate of consumption of freshwater fish obtained from rivers that receive TCDD discharges. Because commercial freshwater fishers do not exist on Maine rivers, any freshwater fish that are eaten have been caught by anglers. A statewide mail survey of Maine's licensed anglers was undertaken to characterize rates of fish consumption from rivers and streams in Maine. The survey was mailed to 2,500 licensed resident anglers who were randomly selected from state license files. The response rate of 70% (based on deliverable surveys) resulted in a usable sample of 1,612 anglers. Results of this study indicated that, if fish are shared with other fish eaters in the household, the annual average consumption of freshwater river fish per consuming angler in Maine is 3.7 g/d. Comparisons of findings of this study and of studies in other regions of the United States show considerable variations in fish consumption rates, supporting the use of state- or region-specific estimates of fish consumption in establishing water quality regulations for persistent, biologically accumulative compounds.

As society attempts to reduce the amounts of contaminants released into surface water resources, and to determine appropriate restoration levels for contaminated waters, a critical consideration is the quantity of fish that the public consumes from those waters. Ingestion of freshwater fish is potentially the most common pathway of human exposure to certain chemical contaminants in surface waters (Rifkin and LaKind 1991). Recognizing that a relationship may exist between the presence of contaminants in surface waters and uptake by humans through fish ingestion is only the first step in developing water quality regulations. It is also necessary to determine the quantities of fish consumed, the levels of chemical contaminants in the fish tissues consumed, and the potential toxicity to humans who consume those fish (Sherman et al. 1992). While the health effects of certain compounds have been studied extensively, and levels in fish are frequently monitored, estimates of fish consumption from specific water bodies are not readily available (EPA 1992). This lack of data is due largely to the fact that fishery managers and natural resource agencies are primarily concerned with controlling harvest and not with the final disposition of the harvest. Monitoring the consumption of freshwater fish often does not come under the direct purview of any public agency.

An example of this limitation is the recent rule-making process to set an ambient water quality standard for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) in Maine's rivers. Because there are no commercial freshwater fisheries in the state, only those individuals who consume sport-caught fish have the potential to be exposed to TCDD in the fish from Maine's impacted rivers. Thus, estimation of angler consumption of freshwater fish from affected rivers was critical to the rule-making process in Maine.

TABLE 1.—Existing fish consumption estimates (mean g/d per person). Numbers in parentheses are median values. Consumption estimates from studies on the U.S. population are per capita.

Reference	Consumers studied	All types of fish, all sources[a]	Marine–estuarine fish		Freshwater fish	
			All sources[a]	Sport-caught[b]	All sources[a]	Sport-caught[b]
Fiore et al. (1989)	Wisconsin anglers			26	12	
Honstead et al. (1971)	Columbia River anglers					7.7
Javitz (1980)	U.S. population	14[c]				
Landolt et al. (1985)	Washington anglers			(15)[c]		
NYSDEC (1990)	New York anglers	28				
Pao et al. (1982)	U.S. population	(37)				
Pierce et al. (1981)	Washington anglers			(23)[d]		
Puffer et al. (1981)	California anglers			(37)		
Rupp et al. (1980)	U.S. population	16	14		1.5	
Soldat (1970)	Columbia River anglers					1.8
Turcotte (1983)	Savannah River anglers					31[e]
West et al. (1989)	Michigan anglers				18	7[f]

[a] All sources includes fish purchased in stores and restaurants as well as recreationally caught fish.
[b] Sport-caught includes only fish that have been obtained by angling.
[c] Estimate based on Monte Carlo simulation using frequency distributions for edible weight of fish, fish per trip, trips per year, and household size.
[d] EPA (1989b) estimate.
[e] Based on harvest estimates; no correction for sharing of harvest.
[f] Estimated value based on data presented in Table 19 in West et al. (1989).

There are several reasons why the existing fish consumption estimates derived elsewhere could not be used to infer freshwater fish consumption in Maine. First, fish consumption studies by Javitz (1980), Rupp et al. (1980), Pao et al. (1982), and NYSDEC (1990) did not distinguish between the consumption of commercially harvested and recreationally harvested fish (Table 1). Thus, the fish consumption estimates from these studies include purchased and sport-caught freshwater and saltwater fish. Consumption of saltwater species was not relevant to the TCDD risk assessment for Maine's rivers, and there are no commercial freshwater fisheries on Maine's rivers.

Second, studies by Pierce et al. (1981), Puffer et al. (1981), and Landolt et al. (1985), although focused on consumption of sport-caught fish, gave consumption estimates for marine or estuarine fishes. There are no data available to evaluate the comparability of consumption of recreationally caught saltwater fish with consumption of recreationally caught freshwater fish.

Third, only six studies specifically estimated consumption of freshwater fish (Soldat 1970; Honstead et al. 1971; Rupp et al. 1980; Turcotte 1983; Fiore et al. 1989; West et al. 1989). Of these studies, only four reported consumption rates for sport-caught fish, and only three estimated consumption of sport-caught fish from riverine fisheries. The river studies were conducted in the Pacific Northwest (Soldat 1970; Honstead et al. 1971) and the southeastern United States (Turcotte 1983). These studies demonstrated considerable variation in estimated consumption; mean rates ranged from 2 to 31 g/d per person.

Therefore, to estimate consumption rates of recreationally caught freshwater species in Maine, we conducted a statewide mail survey of licensed resident anglers. We have identified potential issues in developing fish consumption estimates that we hope will stimulate research to enhance the validity and reliability of future fish consumption estimates. It is also our intent to raise fishery biologists' awareness of the need for estimating fish consumption rates so that future studies of fishing effort, when possible, will include estimates of harvest and consumption.

Methods

Sample Selection

Freshwater fish consumption was estimated for adult anglers who held a Maine resident, inland fishing license.[1] Nonresident anglers were not included in the sample because prior research in-

[1] All adult anglers (≥16 years) are required to obtain a fishing license to fish Maine's inland waters, except members of the Penobscot Indian Nation, who can fish riverine waters adjacent to selected portions of their land without a license. The Penobscots must obtain a complimentary license to fish all other riverine and standing waters in the state. Holders of these complimentary licenses were represented in the sample.

dicated that there is substantially more effort each year by resident anglers, and resident anglers are more likely to fish in Maine every year (Boyle et al. 1989). By sampling only licensed resident anglers, consumption data were collected for the subset of licensed anglers who, as a group, were believed to have the greatest potential opportunity for exposure to TCDD.

A sample of 2,500 licensed resident anglers was randomly selected from Maine's license files. Prior research indicated that participation in warmwater fishing is substantially lower than participation in coldwater fishing in Maine, and that the warmwater species with the lowest participation rates were yellow perch *Perca flavescens* and white perch *Morone americana* (Phillips et al. 1990). Multiplying the inverse of the combined rate for participation in yellow perch and white perch fishing by the desired number of consumption observations for perch (100) led us to conclude that we needed to receive 1,363 completed surveys. To determine the sample size necessary to ensure this number of responses, we assumed that 90% of the mailed surveys would be deliverable, that 90% of the 1989 license holders fished in 1990, and that the survey response rate would be 75%. This resulted in a required sample size of approximately 2,000. An additional 500 anglers were added to the sample to compensate for an unknown percentage of Maine anglers who practice catch-and-release fishing or do not consume fish. This procedure ensured that the number of consumption observations for all other fish species of interest would exceed those for yellow perch and white perch.

Because inland fishing licenses are valid for one calendar year, and recording of license sales is not completed by Maine's Department of Inland Fisheries and Wildlife (IF&W) until March of the following year, the sample was selected from among all anglers who held a 1989 fishing license. This process resulted in a sample of anglers who held licenses in both 1989 and 1990. Boyle et al. (1990) surveyed resident anglers licensed in 1987 regarding their open-water fishing effort during 1988 and found this sampling method to be valid.

The mail survey was pretested with 50 randomly selected anglers. Telephone interviews were conducted with 40% of the pretest participants to learn if they had difficulty in answering or understanding any of the questions. Final revisions were made to the survey, based on responses to the telephone interviews and reviews of returned pretest mail surveys.

All open-water fishing in Maine closes on October 31. However, because open-water fishing for most Maine waters (all but one river) closes on September 30, the survey was implemented in mid-October 1990. Postcards were sent 1 week later, thanking those who had already returned the survey, and asking those who had not yet returned the survey to do so. Three weeks later, on November 7, 1990, a follow-up survey packet was mailed to 1,111 anglers who had not yet responded, and the recipients were asked to complete and return the survey by December 3, 1990.

Survey Design

The design of the survey focused on asking anglers to report the disposition, particularly consumption, of freshwater fish they caught in Maine. This strategy differed from some of the previous fish consumption studies where survey respondents were asked to report the number of fish meals they ate each week (Javitz 1980; Rupp et al. 1980; Pao et al. 1982; West et al. 1989; NYSDEC 1990). To address the TCDD issue, it was important to know where the fish were caught and to exclude fish consumption from sources other than Maine's freshwater (i.e., saltwater species or freshwater species purchased at the market). Only 320 km of Maine's rivers, less than 1% of all riverine environments in Maine, were potentially contaminated by TCDD. Therefore, to obtain a usable sample and to provide an appropriate context, anglers were asked about their fish consumption from flowing (rivers, streams, and brooks) and standing (lakes and ponds) water bodies.

Each respondent was asked to report how many trips had been made to ice fish, open-water fish in standing waters, and open-water fish in flowing waters during the last completed season. Anglers were also asked to report the number of each species of fish caught during the 1990 open-water season and the 1989–1990 ice-fishing season. For fish caught during open-water season, anglers were asked to report the number of fish consumed for each of 15 groups of species, and to identify the number taken from flowing or standing water bodies. Anglers were also asked to estimate the average length for each species of fish that was eventually consumed. In addition to those fish caught by the responding angler, the respondents were asked to describe the number, species, and average length of each sport-caught fish they had consumed that had either been obtained from other members of their households or from individuals outside of their households.

TABLE 2.—Regression parameters for weight–length equations and edible portion (E) of fish species harvested by freshwater anglers in Maine. NR = not reported.

Species	Regression coefficients: Intercept	Regression coefficients: Slope	Length range[a] (mm)	Water body and location	Source[b]	E[c]
Landlocked salmon (lacustrine Atlantic salmon *Salmo salar*)	−5.145	3.035	270–750	Rivers and lakes, Maine	IF&W	0.40[d]
Atlantic salmon	−5.038	3.00	NR	Unspecified, Scotland	Carlander (1969)	0.40[d]
Lake trout *Salvelinus namaycush*	−5.879	3.306	290–840	Rivers and lakes, Maine	IF&W	0.30
Brook trout *Salvelinus fontinalis*	−5.054	3.022	150–750	Rivers and lakes, Maine	IF&W	0.30
Brown trout *Salmo trutta*	−5.096	3.037	167–936	Rivers and lakes, Maine	IF&W	0.30
Yellow perch *Perca flavescens*	−3.519	2.390	127–320	Rivers and lakes, Maine	IF&W	0.30
White perch *Morone americana*	−5.273	3.177	100–457	Rivers and lakes, Maine	IF&W	0.30
Largemouth bass *Micropterus salmoides*	−3.844	2.606	209–686	Rivers and lakes, Maine	IF&W	0.30[d]
Chain pickerel *Esox niger*	−5.491	3.098	229–566	Unspecified, Florida	Carlander (1969)	0.30
Lake whitefish *Coregonus clupeaformis*	−5.677	3.241	NR	Lake Superior, USA–Canada	Carlander (1969)	0.30
Brown bullhead *Ameiurus nebulosus*	−5.061	3.065	152–192	Lake Butte des Mortes, Wisconsin	Carlander (1969)	0.30
White sucker *Catostomus commersoni*	−5.395	3.223	NR	Shadow Mt. Lake, Colorado	Carlander (1969)	0.30
Creek chub *Semotilus atromaculatus*	−3.972	2.98	NR	Des Moines River, Iowa	Carlander (1969)	0.30
Rainbow smelt *Osmerus mordax*	−6.2	3.40	80–220	5 lakes in the Sebago region, Maine	IF&W	0.78[d]
Redbreast sunfish *Lepomis auritus*	−4.69	3.01	NR	Unspecified, Alabama	Carlander (1977)	0.30

[a] Represents the range of lengths of fish used for the regression analysis.
[b] IF&W = Maine's Department of Inland Fisheries and Wildlife (unpublished data).
[c] Portion of whole fish that is edible, based on EPA (1989b), except where noted.
[d] Based on Maine-specific data collected by ChemRisk (unpublished data).

Estimating Fish Consumption Rates

The total weight of freshwater fish from each source that was consumed within each respondent's household was estimated from respondent-provided data on quantity and average length of each fish species eaten that was obtained as a result of the respondent's, other household members', and nonhousehold members' fishing activities. The weight of fish consumed for each species group was estimated as follows:

$$C_i = Q_i \times W_i \times E_i; \quad (1)$$

C_i = total weight (g) of species group i consumed within the angler's household;
Q_i = number of fish of species group i consumed within the angler's household;
W_i = weight (g) per fish of species group i, based on reported average length (lengths were reported in inches but converted to millimeters);
E_i = portion of fish weight that is edible for species group i.

Data on the number of fish consumed were directly obtained from survey responses. The weight was predicted by using the reported average lengths from the survey and length–weight regression equations estimated by IF&W based on several years of length and weight measurements from rivers and lakes in Maine (Table 2). For those species for which Maine-specific equations were not available, the appropriate relationships were obtained from Carlander (1969, 1977).

Because not all of a fish is edible, it was necessary to characterize the edible portion of a whole fish (E_i). Stansby and Olcott (1963) reported that commercial filleting of finfish yields between 20 and 40% edible tissue and that actual yield depends upon the species. The EPA (1989a) has recommended that 30% be used to characterize the edible portion of finfish.

To explore the range and variability of the edible portion, studies were undertaken to estimate the edible portions (fillets) of smallmouth bass *Micropterus dolomieu* and landlocked salmon in

Maine. Twenty-two smallmouth bass were collected from two Maine rivers and 12 landlocked salmon were collected from one river. The whole fish were weighed and then carefully filleted to remove as much flesh from the bones as possible. Fillets from each fish were then weighed, and the fillet weight was compared with the whole-body weight for that fish to determine the edible portion. For smallmouth bass, the mean edible portion was 30%, with a 90% confidence interval ranging from 27 to 30%. The mean edible portion for landlocked salmon was 37% with a 90% confidence interval ranging from 36 to 39%. For the current analysis, the results of the landlocked salmon analysis were used to assume edible portions of 40% for landlocked salmon and Atlantic salmon. The EPA (1989a) recommendation, confirmed by the smallmouth bass analysis, was used to assume an edible portion of 30% for all species in Table 2 except rainbow smelt. For this species, we assumed that half of those consumed were eaten without the head or viscera, and half were eaten with the viscera but without the head. Rainbow smelt data were not available, but for landlocked salmon, the body without the head and viscera represented 68% of the whole fish weight and the body without the head represented 87%, giving an average edible portion of 78%. This average value was used for rainbow smelt.

The total freshwater fish weight consumed from Maine rivers and streams by the angler and other people in the household was then calculated as the sum of C_i for the 15 groups of species. Daily freshwater fish consumption for each individual respondent was estimated by summing the source-specific rates (e.g., open-water fishing, ice fishing), and then dividing by the number of fish consumers residing in the respondent's household and the number of days in a year. To estimate rates of consumption from rivers and streams, equation (1) was used but Q_i and W_i were based only on fish that had been reportedly harvested from rivers or streams during the season.

Our initial analysis of consumption rates was based on the assumption that all freshwater fish obtained for consumption by the angler were shared equally with other household members who consume fish. This assumption was also used by Puffer et al. (1981) and is the approach supported by EPA (1989a). Some researchers have divided total fish consumed by the total number of persons in the household to obtain per-capita fish consumption estimates (Pierce et al. 1981; Landolt et al. 1985). Whereas this approach may be reasonable for estimating consumption of marine species, it is questionable for estimating consumption of freshwater fish because the percentage of the population that eats freshwater species is generally lower than the percentage that consumes marine fish (Rupp et al. 1980). We also conducted a sensitivity analysis to consider the impacts of different assumptions about sharing on consumption rate estimates. Three scenarios were considered: (1) all household fish consumers eat an equal share of consumed fish; (2) only adults in the household consume fish; and (3) the angler alone consumes all of the fish reported.

Statistical analyses were conducted without assuming a distributional model. Because of certain physical limitations (e.g., the high number of zero consumers and limited number of high consumers), fish consumption data do not fit a standard distribution model. To force a fit of these data to a standard model would obscure the true nature of the distribution.

Results

In total, 1,612 surveys were completed and returned, representing 70% of the deliverable surveys. Of these, 1,251 (78%) of the respondents reported having fished during the 1990 open-water season or the 1989–1990 ice-fishing season. Also, 118 individuals did not fish but consumed freshwater fish caught by other anglers, either within or outside of their households. These 118 respondents, with the 1,251 who fished, constituted the 1,369 angler observations (85% of total responses) used in data analyses.

In total, 599 (44%) of the respondents indicated that they ice fished, and 1,127 (82%) of the respondents participated in open-water fishing during the period of interest. Of the individuals who open-water fished, 93% reported having fished in ponds or lakes and 66% reported having fished in streams and rivers.

Twenty-three percent of all anglers surveyed reported that they consumed no freshwater fish caught in 1990. Forty-three percent of the river anglers indicated that they did not consume fish from rivers or streams during the 1990 season, and 19% of river anglers consumed no freshwater fish from any source during that period.

The median fish consumption per angler for those who had eaten fish was 2.0 g/d based on catch from all waters and 0.99 g/d based on fish taken from flowing waters (Table 3). The arithmetic mean consumption by consuming anglers was 6.4 g/d (all waters) and 3.7 g/d (flowing waters). These arithmetic means represented the 77th

TABLE 3.—Estimates of fish consumption (g/d per person) by anglers licensed to fish in Maine's lakes, ponds, streams, and rivers during the 1989–1990 ice-fishing or 1990 open-water seasons. Estimates are based on rank except for those of arithmetic means.

Percentile	All waters: All anglers[a] (N = 1,369)	All waters: Consuming anglers[b] (N = 1,053)	Rivers and streams: River anglers[c] (N = 741)	Rivers and streams: Consuming anglers[b] (N = 464)
50th (median)	1.1	2.0	0.19	0.99
66th	2.6	4.0	0.71	1.8
75th	4.2	5.8	1.3	2.5
90th	11	13	3.7	6.1
95th	21	26	6.2	12
Arithmetic mean[d]	5.0 (79)	6.4 (77)	1.9 (82)	3.7 (81)

[a] Licensed anglers who fished during the seasons studied and did or did not consume freshwater fish, and licensed anglers who did not fish but ate freshwater fish caught in Maine during those seasons.
[b] Licensed anglers who ate freshwater fish caught in Maine during the seasons studied.
[c] Those of the "all anglers" category who fished on rivers or streams.
[d] Values in parentheses are percentiles at the mean consumption rates.

and 81st percentiles of the consumption distributions, respectively.

Consumption estimates varied depending on how fish were shared among household members (Table 4). If we assumed that only the angler ate all of the fish consumed, then median rates increased by roughly a factor of 2.5 relative to the scenario in which fish are shared by all household fish consumers. If we assumed that fish were shared by adults in the household, median consumption estimates increased by approximately a factor of 1.2.

Discussion

The EPA (1989b) has recommended that when data on local consumption are not available, a default value of 30 g/d per person "be used to represent consumption rates for recreational fishermen in any area where there is a large water body present and widespread contamination is evident." This rate is the average of the median consumption rates derived in two studies of marine anglers (Pierce et al. 1981; Puffer et al. 1981). Application of this rate to TCDD rule-making for Maine's rivers is inappropriate because it is based on the consumption of marine species. Furthermore, TCDD discharges are not widespread in Maine, but rather affect only 320 (0.5%) of the 59,500 km of rivers and streams in the state. In its recently proposed document entitled "Estimating Exposures to Dioxin-Like Compounds," EPA (1992) has revised its approach to estimating fish consumption from a single small water body and has indicated that a consumption estimate ranging from 1 to 4 g/d may be more appropriate under these circumstances.

The results of the Maine angler survey demonstrate a median consumption per consuming resident sport angler of 2.0 g/d for all freshwater finfish and 0.99 g/d for fish from flowing bodies of water. Both of these estimates are considerably lower than the median value of 30 g/d previously recommended by the EPA, but fall within the revised EPA recommendation of 1–4 g/d.

These consumption estimates fall at the low end of the range of reported consumption estimates for freshwater fish in other geographic locations (Table 1). Although differences could be due to survey methodology, average lengths of fish and harvest rates reported by survey respondents were consistent with IF&W data. Thus, we believe that these differences are likely due to differences in

TABLE 4.—Sensitivity analyses of the effects of assumptions about sharing of fish among household members on estimated consumption rates (g/d per person).

Percentile	All household consumers share: All waters	All household consumers share: Rivers and streams	Only adults share: All waters	Only adults share: Rivers and streams	Anglers are only consumers; no sharing: All waters	Anglers are only consumers; no sharing: Rivers and streams
50th (median)	2.0	0.99	2.3	1.2	5.0	2.5
66th	4.0	1.8	4.4	2.0	9.1	4.1
75th	5.8	2.5	6.6	3.0	13	6.1
90th	13	6.1	16	6.5	32	14
95th	26	12	28	20	57	27
Arithmetic mean[a]	6.4 (77)	3.7 (81)	7.5 (78)	4.5 (83)	15 (78)	8.9 (83)

[a] Values in parentheses are percentiles at the mean consumption rates.

catch rates, fish size, and length of fishing seasons in Maine relative to other geographic locations. The magnitude of variation of fish consumption estimates reported in Table 1 demonstrates that fish consumption does vary geographically and underscores the need to develop more extensive data on fish consumption so that regional variations can be considered.

It is important to recognize that consumption is likely overestimated in the current study for the purpose of TCDD rule-making in Maine. First, the study was designed to collect data on consumption from all flowing bodies of water, and not just the 320 km of contaminated water. Thus, although individuals may fish in affected river reaches some of the time, it is highly unlikely that all fishing effort is focused on these waters, particularly because there are numerous alternative fisheries in close proximity to each river. Over 80% of Maine's resident anglers fish two or more bodies of water each year, approximately 60% fish three or more, nearly 40% fish four or more, and most riverine fishing in Maine occurs in headwaters and small streams and brooks, not in main stems of larger rivers where TCDD may be present (K. J. Boyle, unpublished data). Consequently, whereas the estimates for rivers and streams include all consumed fish from rivers and streams during the season, it is likely that only a portion of the consumption can be attributed to a single water body.

Second, in a study done for the U.S. Fish and Wildlife Service, Westat (1989) reported that 6-month or 1-year recall periods produce "substantial overestimates" of fishing participation (see also Chu et al. 1992). If participation estimates are overstated in a 6-month to 1-year recall study, it may also be reasonable to assume that consumption is overestimated due to recall bias. To date, there have been no studies specifically conducted for the purpose of evaluating recall bias in fish consumption surveys. This issue needs to be addressed in future studies of fish consumption.

Although fish consumption may be estimated by equating it to harvest, this approach inappropriately assumes that all harvested fish are consumed by the angler. In fact, we found that approximately 30% of the harvested fish were either thrown away, given away, used as bait, or fed to pets. Furthermore, anglers may share catch with friends or family members. Thus, equating the amount of fish harvested with consumption, even if adjustments are made for the edible portion, will overestimate fish consumption.

As noted earlier, some researchers have asked respondents to recall the total number of fish meals consumed over a period of time and to estimate the average size of those meals (West et al. 1989; NYSDEC 1990). This approach was not used in the current study because it was critical to collect information on the sources of the fish consumed. Anglers were surveyed, rather than other household members, because it was believed that they would be best able to accurately report where the fish had been caught. This is an important issue for future research in that anglers may be able to accurately report catch location, a critical issue in contamination studies, but may not accurately report consumption by all household members. Alternatively, household members may be able to report their consumption habits but may not be able to identify the locations from which the fish have been obtained.

Other issues that require further investigation when assessing exposure to chemical contaminants in fish are the sizes of fish consumed, the number of individuals who share in consumption, and the species consumed. Consideration should be given to the household member who consumes the largest quantity of fish, and the sex and age composition of fish consumers. Estimates of exposure must also consider the differences among species in their potentials to accumulate chemical contaminants in their tissues. Anadromous species such as Atlantic salmon and rainbow smelt are likely to have low body burdens of chemical contaminants, whereas other species indigenous to riverine environments, such as white perch, yellow perch, brown bullhead, creek chub, and white sucker, may have larger body burdens of chemical contaminants. All of these factors, although not necessary in estimating total fish consumption, may be crucially important in assessing exposures due to fish consumption.

The need to develop fish consumption estimates is not motivated solely by a single contaminant like TCDD but also arises for numerous other contaminants in aquatic ecosystems. If fish consumption levels for particular types of water bodies in specific regions of the country are known, it will be possible to assess human exposure to any contaminant once the concentration in edible fish tissue has been determined. The specific contaminant being addressed will, however, define the location and extent of fish consumption data required. Therefore, regular collection of fish consumption data as a part of the fishery management process will enhance future assessments of potential contamination and the ultimate restoration of contaminated waters.

Regulators are often faced with multiple factors that need to be considered in rule making, including public health risks, the size of the potentially affected population, and social factors. Unnecessarily stringent water quality standards could result in substantial economic and social costs. The methodology used in this study allows estimates of consumption to be derived for each respondent. It provides regulators with a full distribution of consumption estimates to be used in the decision-making process. The selection of the most appropriate consumption percentile to be used can then rightfully be made as part of the risk management or policy decision.

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